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Feasibility and Performance of Low-Volume Roadway Mixture Design

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13. Abstract

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criteria and the revised payment adjustment schedule, DOTD proposes to evaluate the performance of these asphalt pavements and evaluate the effect that the new payment adjustment schedule may have on the performance.

Project Review Committee

Each research project will have an advisory committee appointed by the LTRC Director. The Project Review Committee is responsible for assisting the LTRC Administrator or Manager in the development of acceptable research problem statements, requests for proposals, review of research proposals, oversight of approved research projects, and implementation of findings.

LTRC appreciates the dedication of the following Project Review Committee Members in guiding this research study to fruition.

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Feasibility and Performance of Low-volume Roadway Mixture Design

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Abstract

The typical low-volume project in Louisiana is mill and replace (~2 in.) with no base repair. The less than ideal base conditions often lead to density variations in the asphalt wearing course. The 2016 Louisiana Department of Transportation and Development specification based pay for asphalt tonnage on density under a percent within limits (PWL) pay structure. In an effort to provide Louisiana contractors with a more efficient hot mix asphalt (HMA) mix design for low-volume roadways, the Louisiana Department of Transportation and Development (DOTD) introduced criteria for roads with average daily traffic (ADT) under 1000. One way to accomplish this was to introduce a new set of criteria that would yield a mix that could achieve a passing density with less effort; this would not unjustly penalize contractors for density variation on low-volume projects with varying base conditions. In addition to the revised asphalt mixture criteria, the specifications introduced a revised payment adjustment schedule that is based on the average roadway density of the asphalt lot rather than the PWL pay schedule. With the implementation of the low-volume roadway mix design criteria and the revised payment adjustment schedule, DOTD proposes to evaluate the performance of these asphalt pavements and evaluate the effect that the new payment adjustment schedule may have on the performance.

Acknowledgments

The authors acknowledge the financial support for this study by the Federal Highway Administration (FHWA), the Louisiana Department of Transportation and Development (DOTD), and the Louisiana Transportation Research Center (LTRC). The authors would like to express thanks to Samuel Cooper, III, Jeremy Icenogle, Hannah Boggs, Angela LeMay and the district personnel who assisted with obtaining asphalt mixtures for testing.

Implementation Statement

The low-volume mixture criteria have already been implemented into the standard specifications. This research will seek to evaluate the performance and cost effectiveness of the implementation, as well as recommending any necessary revisions to the payment schedule.

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Introduction

During specification meetings between the Louisiana Department of Transportation and Development (DOTD) and asphalt contractors around the state, a concern was raised regarding the payment methods for low-volume roadways. At the time, DOTD was using the "percent within limits" (PWL) model to determine payment for all roadways. The PWL model uses a statistical analysis of the roadway density to determine the total estimated percentage of the lot that meets specification; however, contractors felt that when roadway plans only call for a mill and overlay, with no base course repairs, the PWL model may lead to penalties due to lower densities that may be a result of subpar base courses. Instead of removing the PWL model altogether, DOTD decided to allow for payment to be based upon the average density of the roadway. With this change in the payment model, there were some concerns that the change in the payment model may lead to lower densities which could result in reduced performance and service life. In order to address these concerns, the Louisiana Transportation Research Center (LTRC) conducted research that resulted in a new specification and payment schedule for low ADT mixtures.

The research conducted by LTRC aimed to develop an asphalt specification that would yield mixtures with adequate impermeability at 92% density, resist rutting and cracking, and be easier to construct, thus reducing construction costs. During the course of research, an analysis was also done to determine the traffic volume criteria that would be suitable for the specification. It was determined that an ADT ≤ 1000, which covers approximately 25% of the roadways in Louisiana, would be a sensible traffic volume for the new criteria. The research developed a new specification, which allows a 0.375-inch nominal maximum aggregate size (NMAS) mix, a size previously not allowed, and a 0.5-inch NMAS mix. Additionally, the existing payment adjustment schedule for minor mixtures was revised to include the mixtures. The new specification and revised payment schedule was added to the *Louisiana Standard Specifications for Roads and Bridges* in the 2018 Supplemental Specifications.

Currently, the specification is only being used by one contractor in the state and another contractor has submitted a low-volume mix design that is pending approval. As of this report, approximately 22 projects utilizing the new specification were constructed or scheduled to be constructed.

Literature Review

Low-volume roads are an important part of the United States roadway network as they often play a vital role in the movement of materials and products from rural communities to the more populated areas of society [1]. Various types of industries, such as the agriculture and logging industry, put a lot of strain on these roads; therefore, the need for a durable pavement design is essential [2]. In addition to the economic factors, the largest percentage of roads in the nation are categorized as low-volume roads. A lot of times low-volume roads are managed by local agencies and are often done so with limited resources, and in many cases the roadway structures evolved without thorough engineering designs [1]. Despite this fact, the development of specific mix design procedures to meet the unique needs of low-volume roads has been historically overlooked. This has led to low-volume roads being designed with conventional design methodologies. Often these methods provide substantial structural sections for the low-volume pavements, but these designs may be unnecessary and likely result in fewer miles of low-volume pavements being constructed annually [2].

Others concerns that research looked to address include: DOTs and contractors concern about superpave mixture being too lean [3]; research that has shown that the superpave N_{design} values should be lowered for projects with low traffic volume [4]; and superpave HMA compaction over poor existing base materials resulting in insufficient compaction and lower than target densities [5].

A lot of attention has been paid to high-volume roadways since the introduction of the superpave mix design method, but paving on low-volume roads has many characteristics that are quite different from their high-volume counterparts; such as mix design performance requirements, aggregate requirements and availability, and project budget levels [6]. In his research titled "Superpave Mix Designs for Low-Volume Roads," Engle (2004) sought to determine the issues that affect the use of superpave on low-volume roads, and the issues evaluated included economics, resources and constructability. The research found that using superpave mix designs for low-volume roadways did not cause a significant price increase, and that the cracking and rutting performance of the roadways was enhanced [6]. In addition to Engle's research, Mogawer et al. (2004) conducted research to develop a mix design system for low-volume roads. This research recommended volumetric targets, compaction levels, and an alternative mix design approach for low-volume roads [5].

Along with the different characteristics, there are also concerns of durability in the low-volume mixtures. These concerns seem to be more significant than stability related problems, and the primary concern in the development of a good mix design system is durability. Additionally, adequate durability must be present to resist the effects of loads and environment and prevent excessive maintenance costs [5].

Typically, low-volume pavements are constructed with standard paving equipment, therefore the mixes must be stable enough to resist excessive deformation during construction. Also, mixes for low-volume roads should be such that they can be compacted to proper density levels using standard construction equipment. Hence, the ideal mix for low-volume pavement must be one that is easy to lay down and compact, has adequate durability, and enough strength to withstand construction and vehicular traffic [5].

Recently, the LTRC conducted research to develop design criteria for low-volume roads that addresses these issues. The result was a set of criteria that aims to increase the asphalt content via lower number of design gyrations (N_{design}) and maximum gyrations (N_{max}), and assist in achieving target densities in the presence of poor existing base materials. LTRC also conducted testing to ensure that the revised asphalt specifications wouldn’t lead to a more permeable mix, thus increasing moisture susceptibility.

Objective

The objective of this research was to evaluate the production practices and construction feasibility of DOTD's low-volume roadway mixture design and to analyze the performance of roadways constructed with these mixtures. The research will also serve to analyze the revised payment schedule for low ADT mainline mixtures and its effect on these roadways.

Scope

Several different resources were employed to achieve the objective of this study. In order to evaluate the production practices of the asphalt mix, samples were collected from various contractors for laboratory testing and an assessment of construction feasibility was made based on these findings. The performance data for the low-volume roadway pavements was obtained via window surveys, visual inspections made by the research team, and a distress survey conducted using an automatic road analyzer. Once the performance of these roadways was analyzed, a correlation was established with the revised payment schedule.

Methodology

Study Approach

The following tasks were planned and conducted to achieve the objective of the research project:

- Task 1 – Conduct literature review
- Task 2 – Develop experimental program
- Task 3 – Data and asphalt sample collection
- Task 4 – Laboratory testing
- Task 5 – Perform data analyses
- Task 6 – Preparation of a draft report

Test Factorial

In order to utilize the modified asphalt criteria and its accompanying payment method, a request must be made by the contractor; therefore, the amount of test candidates was limited to projects in which this payment method was requested. A total of six projects were identified as such. The information for the mixtures is shown in Table 1 and the project locations are shown in Figure 1. The mix IDs shown in the table are consistent throughout the report. The job-mix formulas (JMFs) for each project were compiled as well as the plant report, the roadway report, the pay report, and project design proposal. The asphalt samples were obtained at the asphalt plant on the day it was produced before being bought back to LTRC for testing. Volumetric testing was conducted to determine the air voids (AV), voids in mineral aggregate (VMA), and voids filled with asphalt (VFA). Additionally, the asphalt content was found via the ignition method using AASTHO T 308 as well as the mixture gradation. Finally, samples were prepared and subjected to the laboratory performance testing summarized in Table 2 below.

Table 1. Asphalt mixture information

Project Location	Project No.	Type of Construction	Mix ID	Binder Grade	Rap (%)	NMAS (in.)
LA 772 & LA 773	H.012887	Patch and Overlay	887	PG 67-22	19	0.5
LA 124	H.012598	Patch, Asphalt surface Treatment and Overlay	598	PG 67-22	19	0.5
LA 3239	H.013574	In-Place Cement Treatment and Asphalt Concrete	574	PG 67-22	19	0.5
LA 133	H.012988	Stabilize and Overlay	988	PG 67-22	19	0.5
LA 575	H.013742	Patch and Overlay	742	PG 67-22	19	0.5
LA 582	H.010393	Asphalt Overlay	393	PG 67-22	19.1	0.5

Figure 1. Approximate project locations

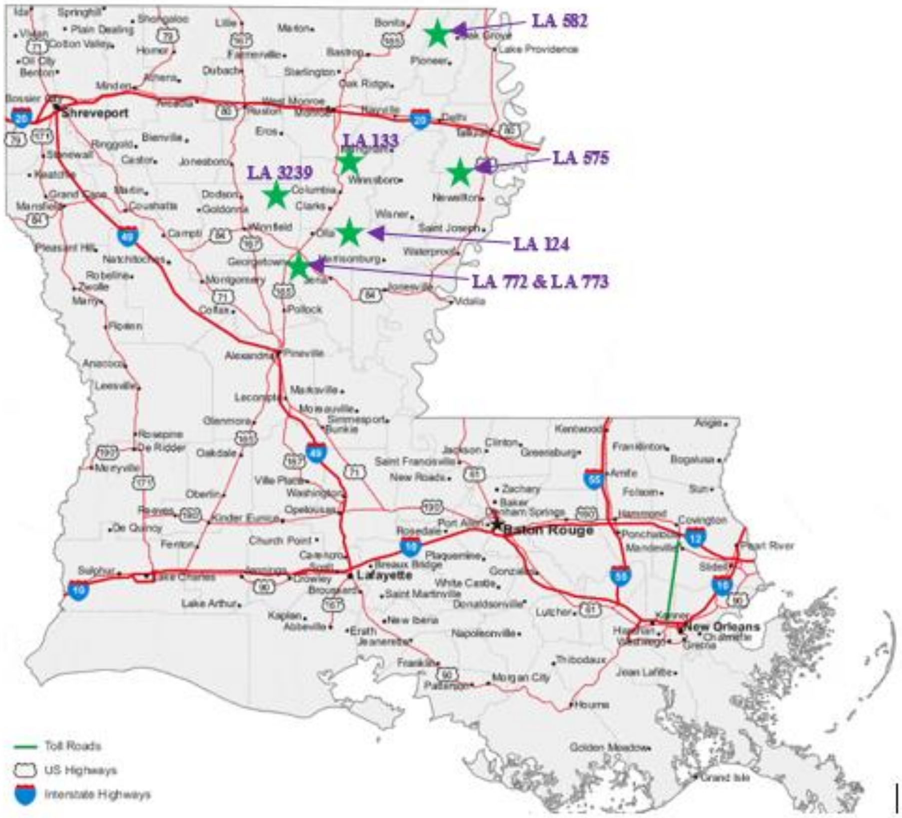


Table 2. Laboratory performance test parameters and protocols

Test Method	**Performance Indicator**	**Test Temperature (C)**	**Test Procedure**
SCB	J_c (kJ/m^2)	25^o	DOTD TR 330
LWT	Rut Depth (mm)	50^o	AASHTO T 324
|E*|	Dynamic Modulus	-4.4^o to 54^o	AASHTO T 342

Low ADT Specification

The new specification can be seen below in Table 3; it differs from the regular specification in that the amount of compaction gyrations for N_{design} and N_{max} are the same at 40 as opposed to a N_{design} of 55 compaction gyrations and a N_{max} of 90 compaction gyrations. This change means that the mix design needs to meet its density target at a much lower gyration count. The new specification also allows for a mixture with a lower NMAS of 0.375 inches, however, no mixture of this size has been produced as of this research study. Additionally, the specification also differs in that the target VMA at N_{design} is a minimum 14% as opposed to 13.5%, and the target VFA range is 72-80% as opposed to 69-80%.

As stated in the DOTD Quality Assurance Manual, "Projects with current plan ADT ≤ 1000 have an option for the contractor to have mainline mixture pay calculated by PWL or average core density." The manual also states that the contractor shall declare the method of pay calculation at the pre-construction meeting, and if they fail to do so, then the pay shall be calculated by PWL. In addition, the manual states that when the contractor chooses mainline mixture average core density pay calculations then the specification for roads ≤ 1000 ADT shall be used for JMF design and production specifications.

Table 3. Asphalt concrete general criteria (<1000 ADT)

Nominal Max., Size Agg.	**0.375 in (9.5 mm)**		**0.5 inch (12.5 mm)**	
Type of Mix	**Incidental Paving**[1]	**Wearing Course**	**Incidental Paving**[1]	**Wearing Course**
Coarse Agg. Angularity, % Crushed, (Double Faced), Min. %	55	75	55	75
Fine Agg. Angularity, Min. %	40	40	40	40
Flat and Elongated Particles (5:1), Max. %	10			
Sand Equivalent, Min. %	40	40	40	40
Natural Sand - Max. %	-	20	-	15
Asphalt Binder	-	Table 502-2	-	Table 502-2
RAP, Max. % of Mix[2]	25	20	-	20
	Compacted Mix Volumetrics			
VMA @ N_{design}, Min. %	15	15	14	15
Air Voids @ N_{design}, %[3]	-	2.5-4.5	-	2.5-4.5
VFA @ N_{design}, %[4]	-	72-80	-	72-80
N_{design} 96.5±1 % (Gyrations)	40			
N_{max} 98 % max. (Gyrations)	40			
LWT, max. rut-design, mm @ # passes, @ 50ºC	10 @ 10,000	10 @ 15,000	10 @ 10,000	10 @ 15,000
Dust/Effective Asphalt Ratio, %	0.6-1.6			
SCB, min, Jc, KJ/m2 @ 25ºC	-	0.5	-	0.5
Design Lift Thickness, inch[5]	≤2.0	Design Lift Thickness, inch[5]	≤2.0	Design Lift Thickness, inch[5]

[1] May be used for minor mix uses (except patching and widening), airports, and other incidental items approved by the Project Engineer. (May be used as a standard roadway mix for local governments.)

[2] RAP is not be allowed for airports or SMA.

[3] Air Voids mix design target is 3.5 percent.

[4] Mix design minimum VFA is 72.0%, Mix design minimum VFA for PG76-22rm is 75.0%

[5] Absolute minimum of lift thickness across width equal to 1/2 inch lower than minimum lift thickness.

Experimental Evaluation

Replicate specimens were prepared for testing. For semi-circular bend (SCB) test, four specimens at each notch depth were evaluated. For the Hamburg loaded wheel test (LWT), two specimens were tested. For the dynamic modulus test, three specimens were tested at four different temperatures. A brief description of each of the test methods are presented in the following sections.

Semi-Circular Bend Test

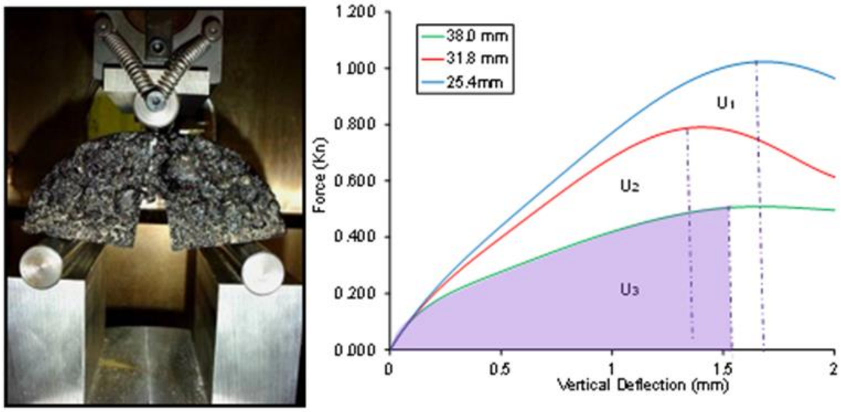
The semi-circular bend test characterizes the fracture resistance of hot mix asphalt (HMA) mixtures based on fracture mechanics principals, and the critical strain energy release rate, also called the critical value of J-integral, or J_c. Figure 2 presents the three-point bend load configuration and typical test result outputs from the SCB test. To determine the critical value of J-integral (J_c), semi-circular specimens with at least two different notch depths need to be tested for each mixture. In this study, three notch depths of 25.4 mm, 31.8 mm, and 38.0 mm were selected and a test temperature of 25°C. The semi-circular specimen is loaded monotonically until fracture failure occurs under a constant cross-head deformation rate of 0.5 mm/min in a three-point bending load configuration. The load and deformation are continuously recorded and the critical value of J-integral (J_c) is determined using the following equation:

$$\mathrm{Jc} = -\left(\frac{1}{\mathrm{b}}\right)\left(\frac{\mathrm{dU}}{\mathrm{da}}\right)$$

where,

b = sample thickness, mm;
a = the notch depth, mm; and
U = the strain energy to failure, kN-mm.

Figure 2. Semi-circular bending test



Hamburg Loaded Wheel Test (LWT)

Rutting performance of the mix was assessed using an LWT, manufactured by Troxler, Inc. of Durham, North Carolina. This test was conducted in accordance with AASHTO T 324, “Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt (HMA).” This test is considered a torture test that produces damage by rolling a 703-N (158-lb.) steel wheel across the surface of a specimen that is submerged in 50°C water for 20,000 passes at 56 passes a minute. The specifications allow for a rut depth of 10 mm at 15,000 passes at 50ºC for the low-volume wearing course.

Dynamic Modulus (|E*|) Test

The dynamic modulus test (|E*|), as shown in Figure 3, is used for performance prediction and to the evaluate stiffness of asphaltic mixtures. The test will be conducted at various temperatures, 4.4, 21, 37.8, and 54°C (40, 70, 100, and 130°F) at loading frequencies of 0.1, 0.5, 1.0, 5, 10, and 25 Hz at each temperature according to AASHTO T 342 “Standard Method of Test for Determining Dynamic Modulus of Hot-Mix Asphalt (HMA)”, where master curves are developed for use in performance analysis and pavement response. Each specimen should be tested for each of the 24 combinations of temperature and frequency of loading starting with the lowest temperature and proceeding to the highest. Testing at a given temperature should begin with the highest frequency of loading and proceed to the lowest. Each test specimen is prepared using test specimens cored from 150 mm (6 in.) gyratory compacted mixtures with a diameter ranging from 100 to 104 mm (3.94 to 4.1 in.) plus or minus 1.0 mm (0.04 in.) standard deviation. The specimens are then aged short-term for 4 hours at a temperature of 135°C and brought to testing temperature according to the guidelines prior to the start of the test.

The |E*| device can test one specimen at a time using a hardened steel disk to apply a desired load while an electronic measuring system records all testing data. The specimen is placed into an environmental chamber and a contact load (P_{min}) equal to five percent of the dynamic load is applied. Sinusoidal (haversine) loading ($P_{dynamic}$) is applied to the specimen in a cyclic manner ensuring the axial strains produced by the dynamic load are kept between 50 and 150 microstrain. Table 4 below shows the typical dynamic stress levels for the various testing temperatures. The test specimens are tested from lowest, -4.4°C (40°F), to highest, 54°C (130°F), temperature after preconditioning each specimen with 200 cycles at 25 Hz at stress level corresponding to Table 4. At each of the four specified testing temperatures, load is applied to the specimen from highest, 25 Hz, to lowest, 0.1 Hz, frequency. The number of cycles for each specimen testing sequence is shown in Table 5 below. After testing is completed, the specimens will be discarded and the collected test data will be analyzed.

The dynamic modulus and phase angle, calculated from test results can be used to determine the performance criteria and stiffness of HMA mixtures. The test results include values for time, displacement, and load at the various temperatures and frequencies. Stress and strain values of the testing specimens are determined from the testing results and used to compute the dynamic modulus.

Figure 3. Dynamic modulus test system

(a) FHWA SPT Tester

b) LTRC UTM-25

(c) Sample Setup for LTRC |E*| test

Table 4. Dynamic stress levels

Temperature, °C (°F)	Range, kPa	Range, psi
4.4 (40)	700-1400	100-200
21 (70)	350-700	50-100
37.8 (100)	140-350	20-50
54 (130)	35-70	5-10

Table 5. Number of cycles for testing sequence

Frequency, Hz	Number of Cycles
25	200
10	200
5	100
1	20
0.5	15
0.1	15

Distress Survey

Roadway Observation

The project roadways are currently being monitored via a window survey approximately every six months. The roadway condition is recorded for each site visit. This observation will continue for several years to check for premature distresses in the pavement. In addition to window surveys, LTRC's Pavement Research Section will periodically analyze the project roadways for rutting and cracking using the automatic road analyzer (ARAN). Figure 4 shows the ARAN and common pavement distresses. The ARAN uses a transverse laser profiler mounted at the back of the survey van to compute the average rut depth of a location. The transverse rutting profile is continuously measured as the survey van drives on a pavement section, and then the average rutting of the pavement section is calculated as the field rutting performance indicator. In order to find the cracking performance, the ARAN utilizes a digital pavement imaging system mounted at the back of the survey van to record the planar view of pavement surface while driving at posted highway speeds. The continuous aerial images of the pavement surface are then processed to detect types and severity of cracks.

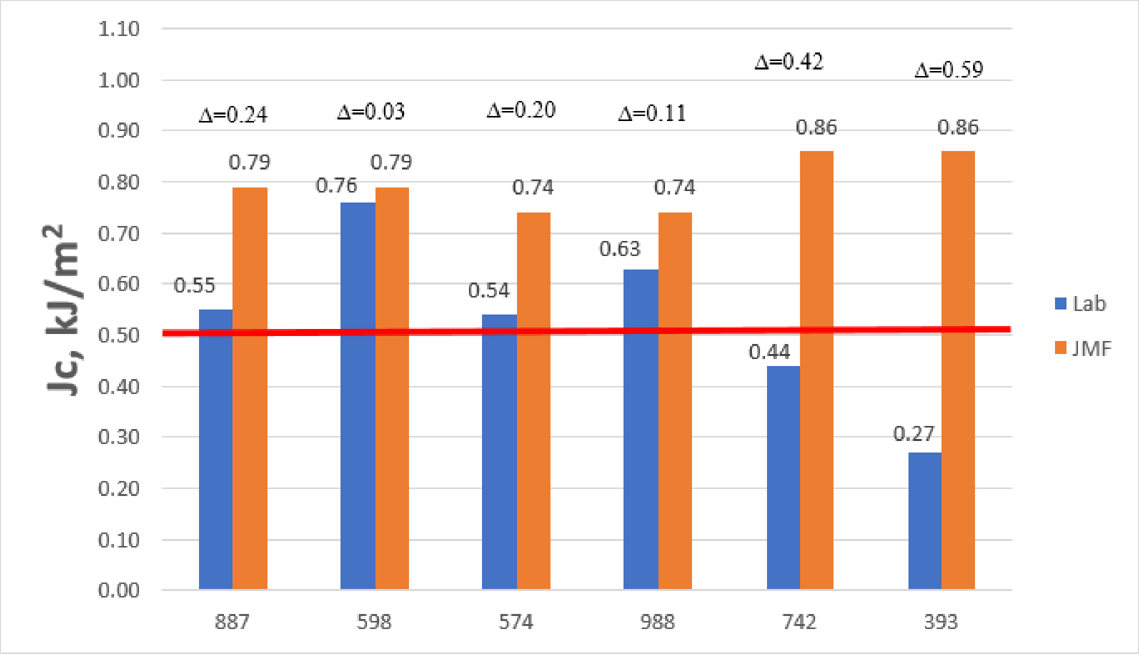
Figure 4. Automatic road analyzer (ARAN) and common distresses

Discussion of Results

Semi-Circular Bend Test

The semi-circular bending test was conducted at an intermediate temperature to determine the cracking resistance of the mixtures. The critical strain energy (J_c) is presented in Figure 5. The specifications for low-volume roadways call for a minimum J_c of 0.5 kJ/m^2. The J_c results from the lab compacted test samples are compared to the J_c reported on the job mix formulas for each mixture and the absolute value of the delta is also shown. It can be seen that all of the JMF samples reported a passing J_c; however, mixtures 742 and 393 did not achieve the minimum J_c when tested in the laboratory. The deltas for each sample set range from 0.03 for mix 598 to 0.59 for mix 393. It should also be noted that all J_c from the JMF were higher than the J_c found in the laboratory.

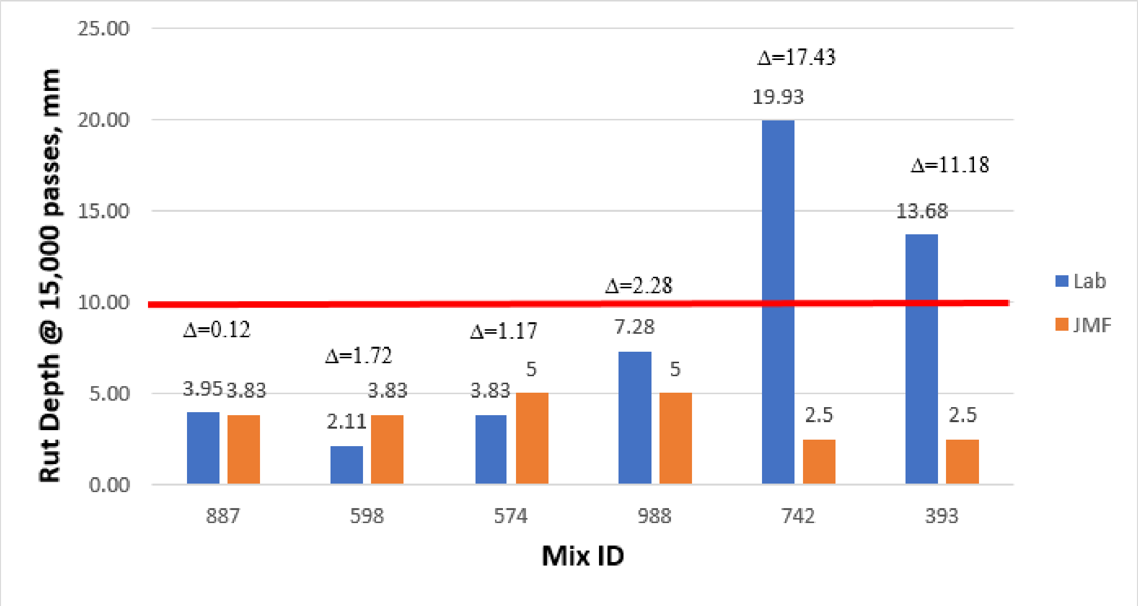
Figure 5. SCB test results



Hamburg Loaded Wheel Test

Rutting is a significant concern for asphalt roadways in Louisiana, therefore the mixtures are subjected to the loaded wheel test to characterize behavior in response to cyclic rolling loads. Figure 6 presents the LWT data generated for this report. The specifications for low-volume roadways call for a maximum rut depth of 10 mm at 15,000 passes. The result from the lab compacted test sample is compared to the rut depth reported on the job mix formula for each mixture and the absolute value of the delta is also shown. It can be seen that all of the JMF samples reported a passing value; however, mixtures 742 and 393 exceeded the maximum allowable rut depth by a considerable margin when tested in the laboratory. The deltas for each sample set range from 0.12 for mix 887 to 17.43 for mix 742.

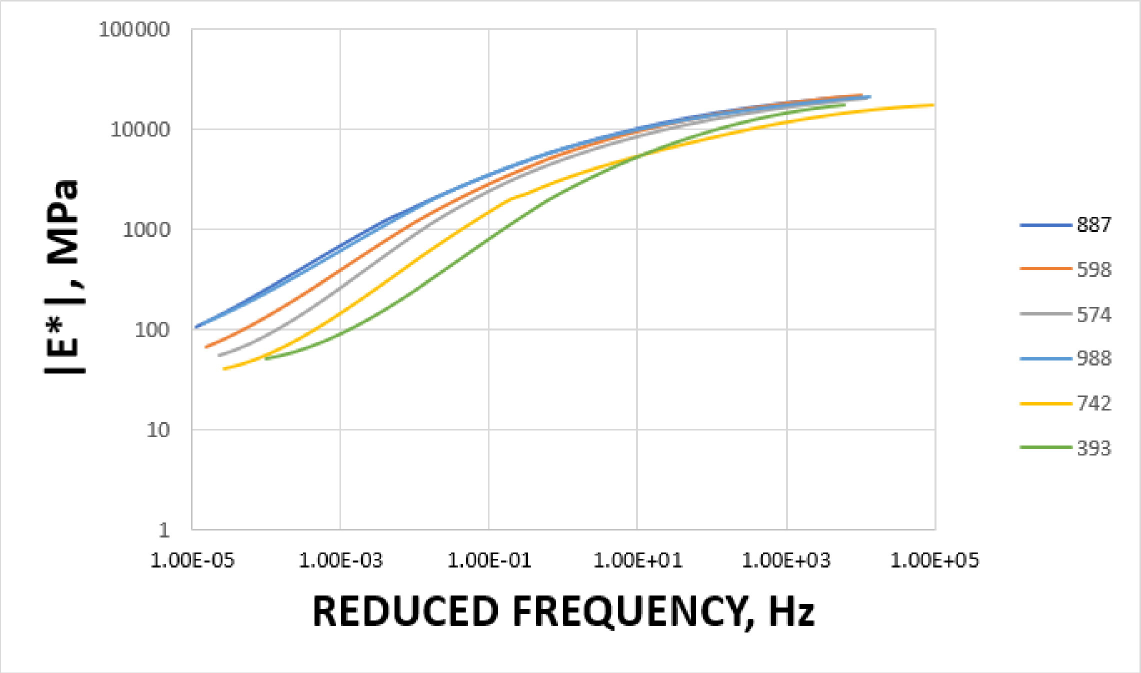
Figure 6. LWT test results



Dynamic Modulus (|E*|)

The dynamic modulus for each mixture was determined in accordance with AASHTO T 342. The test determines the stiffness of the mixture while a repeated axial cyclic load is applied. Figure 7 below displays the master curves of performance for each sample.

Figure 7. Dynamic modulus test results



Volumetrics

Figure 8 presents the air voids reported in the job mix formula and the air voids found in the laboratory. The specifications for low-volume roadways call for the air voids at N_{design} to be between 2.5-4.5%. The result from the lab compacted test sample is compared to the job mix formula for each mixture and the absolute value of the delta is also shown. It can be seen that all of the JMF samples reported a passing value; however, despite numerous attempts in the laboratory, mixture 988 was consistently below the target air void range. The deltas for each sample set range from 0.2 for mix 887 to 1.4 for mix 988.

Figure 8. Air void results

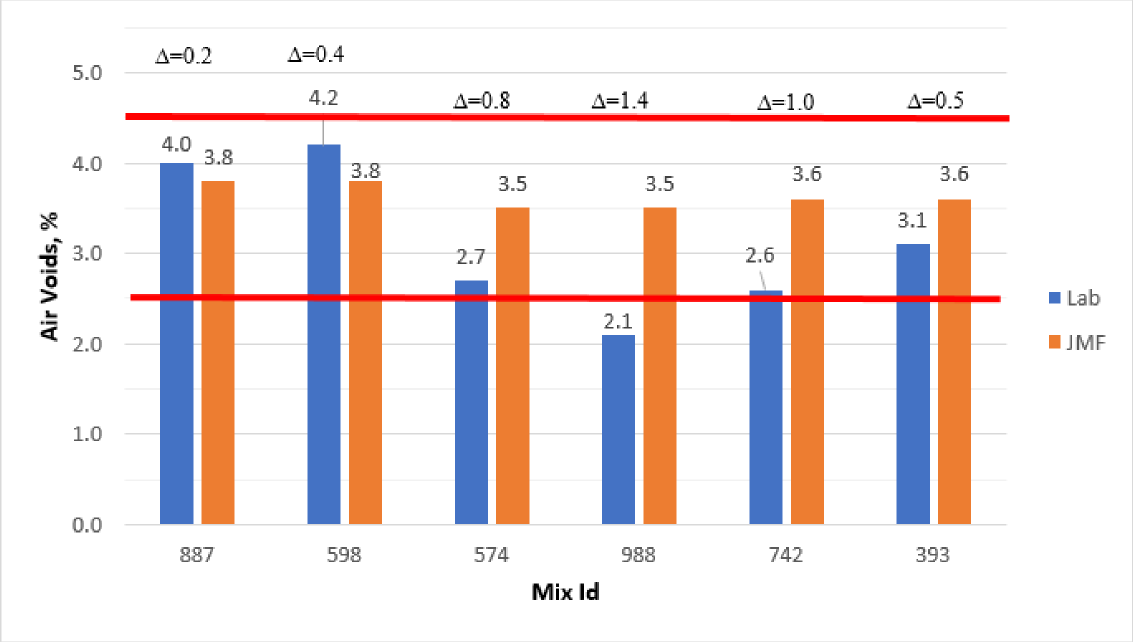


Figure 9 presents the VMA reported in the job mix formula and the VMA found in the laboratory. The specifications for low-volume roadways call for a minimum of 14% at N_{design}. The result from the lab compacted test sample is compared to the job mix formula for each mixture and the absolute value of the delta is also shown. It can be seen that all of the JMF samples reported a passing value; however, the laboratory mixtures 574, 988, 742, and 393 were below the minimum value. The deltas for each sample set range from 0.2 for mix 598 to 1.2 for mixtures 988 and 393.

Figure 9. VMA results

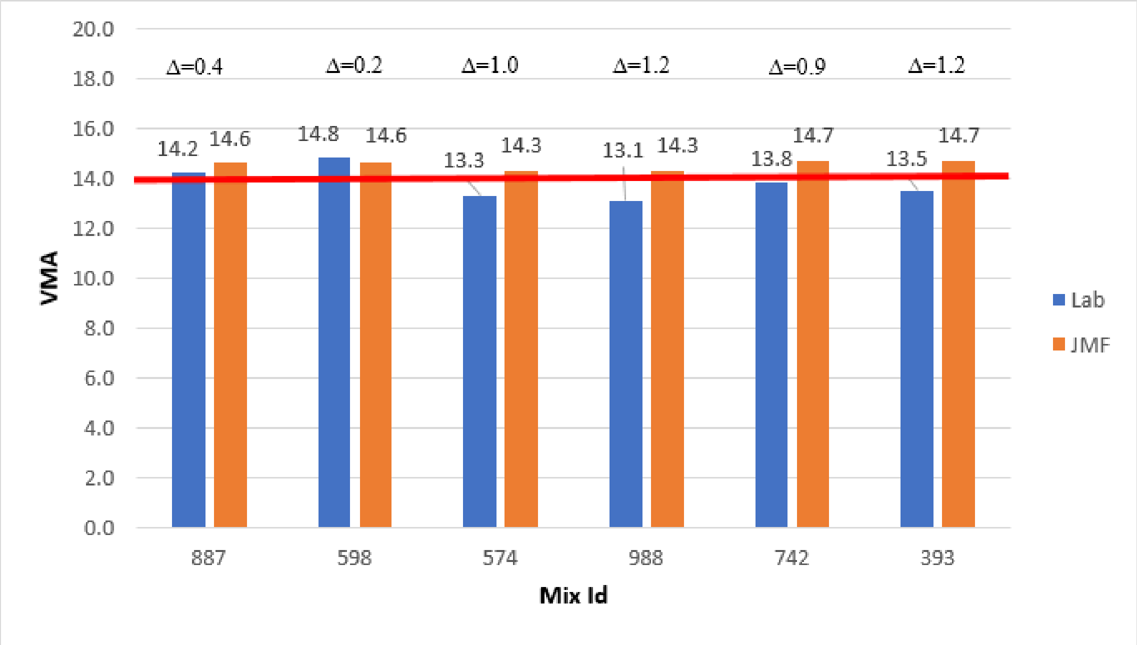


Figure 10 presents the VFA reported in the job mix formula and the VFA found in the laboratory. The specifications for low-volume roadways call for the VFA at N_{design} to be between 72-80%. The result from the lab compacted test sample is compared to the job mix formula for each mixture and the absolute value of the delta is also shown. It can be seen that all of the JMF samples reported a passing value; however, the laboratory mixtures 988 and 742 were above the maximum value. The deltas for each sample set range from 2.0 for mixtures 887 and 598 to 8.2 for mix 988.

Figure 10. VFA results

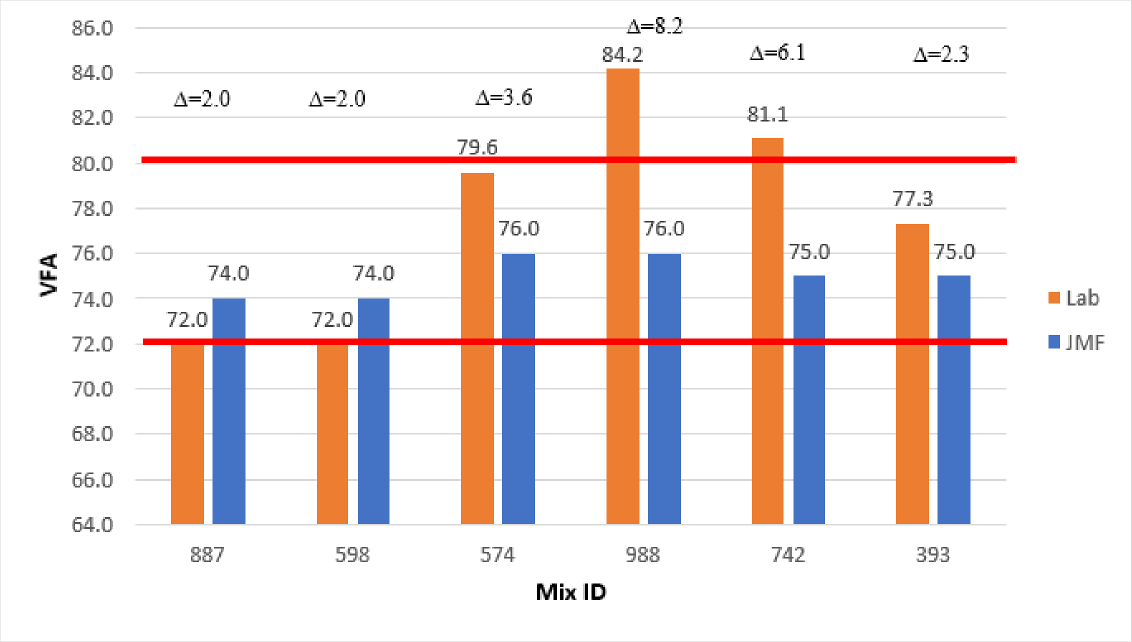
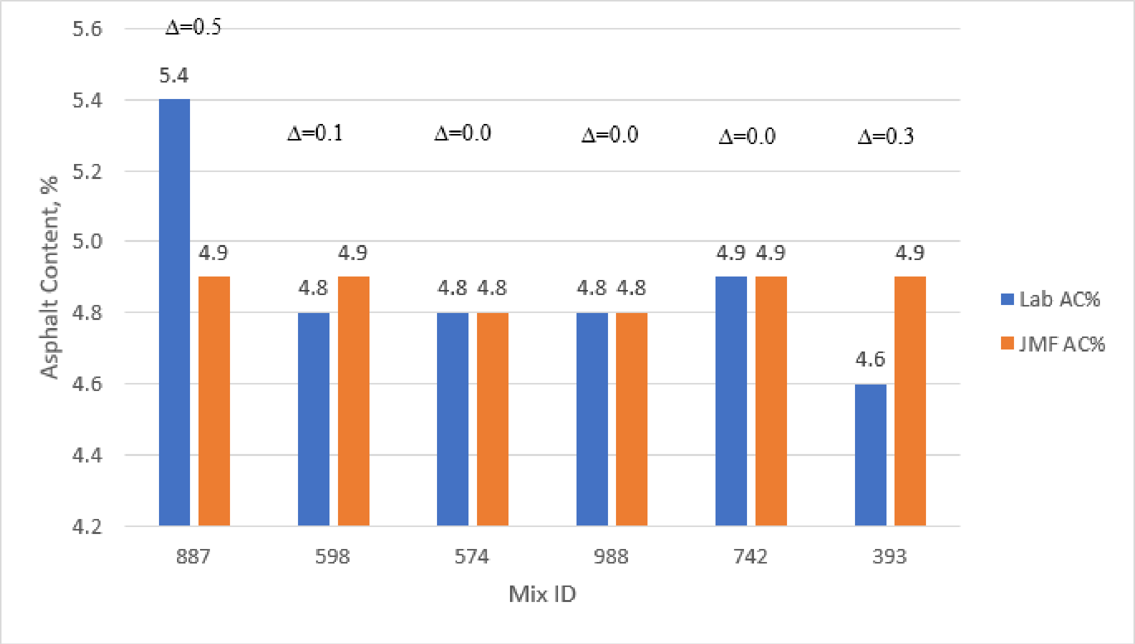


Figure 11 presents the asphalt content reported in the job mix formula and the asphalt found in the laboratory. The result from the lab compacted test sample is compared to the job mix formula for each mixture and the absolute value of the delta is also shown. Sample 887 displayed the largest variance of asphalt content with a difference 0.5, sample 393 had a difference at 0.3, sample 598 had a 0.1 difference and samples 574, 988 and 742 all had no difference between the JMF and lab tested samples.

Figure 11. Asphalt content results



Distress Survey Results

Table 6 presents the average rut depth of the project roadways for each side of the road (northbound/southbound or eastbound/westbound). The roadways have experienced minimal rutting with each road having an average rut depth of 0.1 inches.

Table 6. Roadway rut depth

Mix ID	Average Rut Depth (IN.)
887-NB	0.1
887-SB	0.1
598-NB	0.1
598-SB	0.1
574-NB	0.1
574-SB	0.1
988-NB	0.1
988-SB	0.1
742-NB	0.1
742-SB	0.1
393-EB	0.1
393-WB	0.1

The distress survey included acquiring cracking data for the project roadways. The cracking data that was recorded for project mixes 598 and 574 is shown in the graphs below. The graphs show the total length of cracking per 0.1 log miles. Mixtures 887, 988, 742, and 393 had no cracking to report, which is likely due to the fact that they are relatively new. All of the observed cracking is random cracking, meaning that it is longitudinal and transverse cracking, not alligator cracking. Figure 12 displays the cracking data for mix 598. It had the most cracking between log mile 4 and log mile 8 in both the north and southbound lanes. With 883 feet, the southbound lane had approximately twice as much cracking than the northbound lane, which had 434 feet. The total crack length per lane mile is 47 feet per lane mile.

Figure 12. Cracking results for mix 598

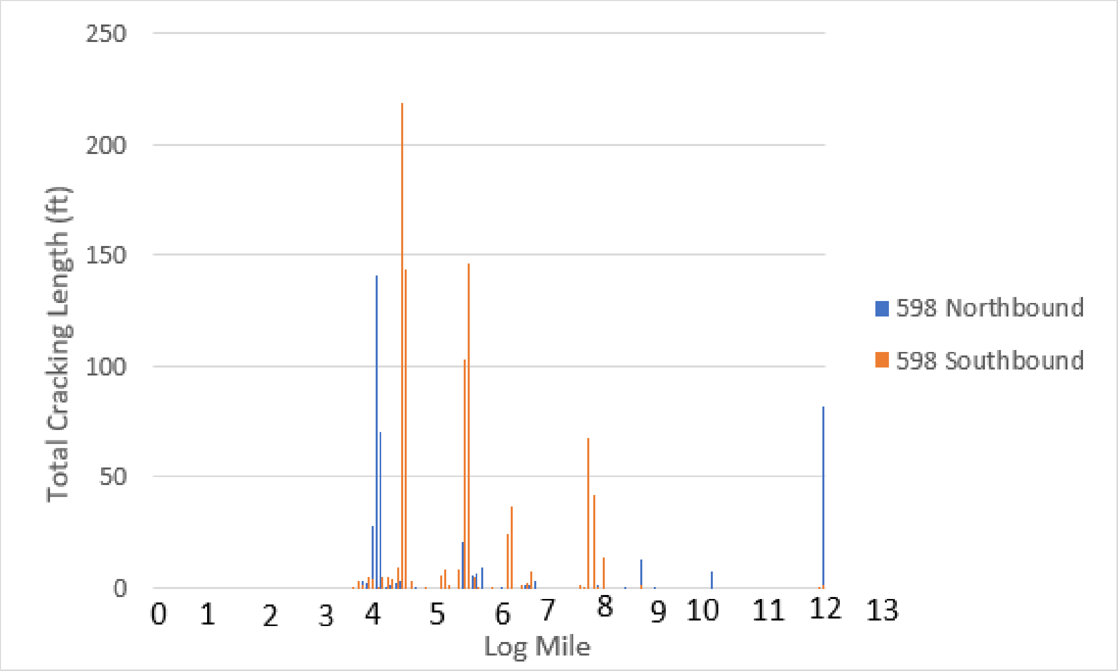
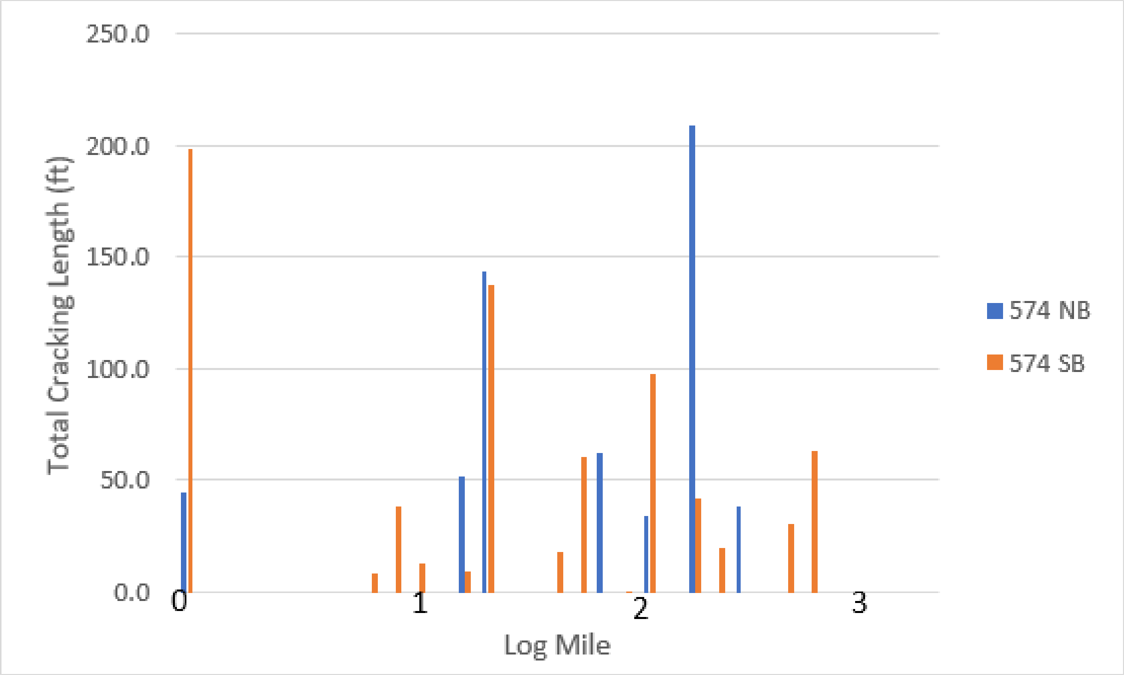


Figure 13 below displays the cracking data for mix 574. The cracking for this project was spread sporadically throughout the roadway but concentrated in certain areas. The southbound lane of the project had more cracking, 737 feet, and the northbound lane had 583 feet of cracking. The total crack length per lane mile is 206 feet per lane mile.

Figure 13. Cracking results for mix 574



Window Survey Results

In addition to the distress survey, the research engineers have made periodic observations via window surveys for the project roadways. The quality of the mat is observed and recorded as well as any potential problems. The window survey results and project roadway pictures can be seen in Table 7 and Figure 14 below.

Table 7. Window survey results

Mix I.D.	Site Visit Date	Observed Condition
887	1/28/2020	Great Condition
	8/17/2020	Great Condition
598	6/4/2020	Great Condition
	1/7/2021	Great Condition
574	6/4/2020	Great Condition
	1/7/2021	Great Condition
988	2/1/2021	Great Condition
742	8/16/2021	Great Condition
393	8/16/2021	Great Condition

Figure 14. Project roadway pictures

Mix 988

Mix 742

Mix 393

Core Density and Payment Data

Table 8 presents the average roadway core density, core standard deviation, payment method selected, and percent pay observed for each of the projects evaluated. One project chose the option to utilize average pay as opposed to PWL. The average densities of the observed projects are above the minimum requirement of 92%. This indicates that the mixture is capable of being sufficiently compacted on typical low-volume pavement structures. Also, the standard deviations of the core densities were less than 1.0 for the majority of the lots. This indicates that the contractor is achieving consistent compaction in the presence of potentially inconsistent base quality. Each lot resulted in 100% pay regardless of the payment method selected.

Table 8. Core density and payment information

Mix ID	Lot #	Average Core Density	Core Standard Deviation	Payment Method	% Paid
887	880	94.3	0.24	Average of Sublots	100
598	884	94.6	1.28	PWL	100
	885	94.2	0.77	PWL	100
574	209	94.9	0.94	PWL	100
	210	94.8	0.15	PWL	100
988	232	95.2	1.89	PWL	100
	233	94.6	0.55	PWL	100
742	137	93.5	1.02	PWL	100
	138	93.8	1.01	PWL	100
	139	94.8	1.37	PWL	100
393	143	95	0.77	PWL	100
	145	94.5	0.87	PWL	100

Conclusions

The objective of this research was to evaluate the production practices and construction feasibility of DOTD's low-volume roadway mixture design and to analyze the performance of roadways constructed with these mixtures. The research also aimed to analyze the revised payment schedule for low ADT mainline mixtures and its effect on these roadways. Based on the results presented, the following conclusions may be drawn:

- The majority of the low-volume mixtures passed the SCB cracking criteria for DOTD. Significant differences were observed between design and production values. The sections will continue to be monitored for impacts on field performance.
- Most of the low-volume mixtures passed the LWT rutting criteria. Insignificant field rutting has been observed through the first summer of use.
- The average and standard deviations of the densities were deemed acceptable, according to both the average and PWL pay structures.
- Additionally, the standard deviation of the densities observed was similar to that of the conventional mixtures used by DOTD. This indicates that the mixture is capable of reaching a consistent density in a low-volume pavement structure.

Recommendations

Based on the outcome of this study, the authors recommend that the low-volume mixture design remain in the specifications. Additionally, the pay schedule for low-volume roads should remain in its current form.

Acronyms, Abbreviations, and Symbols

Term	Description
AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
ARAN	Automatic Road analyzer
AV	Air Voids
cm	centimeter(s)
DOT	Department of Transportation
DOTD	Department of Transportation and Development
E*	Dynamic Modulus
FHWA	Federal Highway Administration
ft.	foot (feet)
HMA	Hot-Mix Asphalt
in.	inch(es)
JMF	Job Mix Formula
LTRC	Louisiana Transportation Research Center
LWT	Loaded Wheel Test
lb.	pound(s)
m	meter(s)
NMAS	Nominal Maximum Aggregate Size
PWL	Pay Within Limits
SCB	Semi-Circular Bend
VFA	Voids filled with Asphalt
VMA	Voids in the Mineral Aggregate

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